Working Paper: The effect of electricity price reform on households' electricity consumption in urban Ethiopia

This paper studies the effect of the revised electricity tariff on households' electricity consumption, and on households' expenditure on alternative fuels. The authors used two rounds of household survey data and six years of electricity consumption data from the utility company. Panel data models and event study analysis were employed to analyse the data. Finally, the authors provide the policy implications of the findings of the study.

February 2022

The effect of electricity price reform on households' electricity consumption in urban Ethiopia

Sied Hassen[1], Abebe D. Beyene[1], Marc Jeuland[2], Alemu Mekonnen[3], Tensay H. Meles[4], Samuel Sebsibie[1], Thomas Klug[2], SubhrenduK. Pattanayak[2], Michael A. Toman[5]

[1] Environment and Climate Research Center, Policy Studies Institute, Addis Ababa, Ethiopia

[2] Sanford School of Public Policy, Duke University, Durham, USA

[3] Department of Economics, Addis Ababa University, Addis Ababa, Ethiopia

[4] School of Economics, University College Dublin, Belfield, Dublin 4, Ireland; Energy Institute, University College Dublin, Belfield, Dublin 4, Ireland

[5]Resources for the Future, Washington, DC.

PSI/ECRC AAU UCL Duke University

Abstract

The price of electricity in Ethiopia was, until recently, among the lowest in the world. Low prices have contributed to a large financial deficit for the Government of Ethiopia-owned electric utility, and have led to a degradation in the quality of the electricity services delivered to customers. In December 2018, the utility increased the electricity tariff, with the aim of helping to finance improvements in the quality of electricity services. This paper studies the effect of the revised tariff on households' electricity consumption and on expenditure on alternative fuels. For this, we used two rounds of household survey data and six years of electricity consumption data from the utility company. The study finds that pre-paid customers, who are all urban residents, reduced their consumption of electricity by about 18kWh, which is equivalent to 8% of their monthly electricity expenditure and around 14% of their daily consumption, in the post-tariff adjustment periods. Overall, however, consumption slightly increased, despite the price increase. The price elasticity of demand for electricity in urban Ethiopia is highly inelastic, and households did not significantly shift to alternative fuels when the price increased from the extremely low levels. The findings indicate that governments and utilities in settings where electricity is priced well below cost-covering levels may be able to increase revenues and improve their balance sheets with relatively modest effects on households' electricity consumption, though effects from more substantial tariff hikes should also be examined.

Key words: electricity price, tariff reform, electricity consumption, event study, Ethiopia

Acknowledgements:

This work was part of the research project 'Impacts and Drivers of Policies for Electricity Access: Micro-and-Macroeconomic Evidence from Ethiopia' under the Applied Research Programme on Energy and Economic Growth (EEG) funded with the UK Department for International Development.

Corresponding author: Email address: seidy2004@gmail.com

1 Introduction

Currently about one quarter of the world's population lack access to electricity. Access challenges in sub-Saharan Africa are particularly dire, as more than 55% of the region's population lacks access to any electricity, and many more have a highly unreliable electricity service (WB, 2019). The lack of access to electricity on the continent creates serious impediments to productive, energy-intensive economic activity, the provision of high-quality public services, the adoption of livelihood-enhancing appliances and technologies, and general quality of life (Blimpo and Cosgrove-Davies, 2019).

Ethiopia has some of the lowest levels of access to electricity globally, as indicated by the percentage of people connected and by average per capita electricity consumption, which was reported to be about130kWhin2019 (IEA, 2020).[1] The national electrification rate is estimated to be 45%, with urban and rural electrification rates of 92% and 29%, respectively (WB, 2018). The low level of electricity access is due to the lack of capital for investment, the lack of private sector participation (i.e. the government is the only producer and distributer of grid electricity), the lack of awareness of renewable energy technology among households, and challenges related to serving rural populations living in remote and mountainous areas. The low financial viability of the power sector in Ethiopia, which is also related to tariffs set well below cost-covering levels, is a particular problem; this discourages the investment needed to ensure reliable energy supply, meet universal access targets, and hasten a modern energy transition.[2]More appropriate pricing of electricity is urgently needed to improve electricity sector performance, and to capture the macroeconomic, fiscal, environmental, and social gains that come with enhanced electricity access.

Against this backdrop, Ethiopia has been investing considerable capital in expansion of energy generation capacity from a range of renewable sources, including from large hydropower investments and distributed renewables such as geothermal, solar, and wind energy installations, in order to meet its national goals and its international Sustainable Development Goal commitments (Ministry of Water, Irrigation and Electricity, 2019). The National Electrification Program 2.0, which was launched in 2017, presents an action plan for achieving universal electricity access by 2025.The objective of the plan is to make Ethiopia 100% electrified in 2025, with 65% through grid and the remaining 35%through investment in decentralised off-grid technologies (solar standalone systems and mini-grids).

As part of the package of interventions in the sector, in 2018 Ethiopia also introduced electricity price reforms aimed at improved cost recovery, which would increase financial support for maintenance and encourage investment in the sector. Prior to this pricing reform, the tariff rate had not been changed since 2006. In December 2018, the government increased residential tariff rates, which are differentiated depending on the level of monthly consumption according to an increasing block tariff (IBT) structure. For example, the increase in the tariff rate (ETB/kWh) in December 2018 ranged from 0 (for those consuming less than 50kWh per month) to 64% for the highest-level electricity consumers (for those consuming above 500 kWh/month). The increases in the tariff rate continued in four phases (December 2018 to December 2021) with increases each December, with high consuming consumers facing a total marginal cost increase of 257% by the end of 2021, if they continue to consume at the levels maintained prior to the start of the reform. These changes are expected to result in a more cost-reflective tariff that will incentivise more efficient electricity use, ease fiscal burdens,[3] and promote investment in infrastructure. In addition to this, the pricing reform aims to motivate and encourage private investment in the off-grid market: the new price will enable private investors to make some profit. In this paper, we examine the impact of the initial phase of the electricity tariff increase on households' electricity consumption using two rounds of panel data and six years of utility billing data, collected from major urban towns in Ethiopia.

Available empirical studies on the impact of electricity pricing reform are scarce, pointing to mixed impacts of higher prices but suggesting generally inelastic demand (Klug *et al*., 2021). Carter *et al*.(2012) found that changes in the electricity rate structure had insignificant impacts on electricity demand among Barbadian households. Also consistent with inelastic response, Silva *et al*. (2009) found that electricity price hikes resulted in a significant increase in households' energy expenditure in Montenegro. Waddamsand Pham (2009) argue that increased tariffs Albania and Bulgaria have greater impacts on the poor and most vulnerable groups of society.

---

[1]The details are found in Section 2. It is retrieved from https://ourworldindata.org/grapher/per-capita-electricity-consumption.

[2]This refers to an attribute of utility companies and is fulfilled when tariff revenues, together with other sources of income, are adequate to cover the cost of service (Huenteler*et al*., 2017).

[3]According to Ethiopian Electric Utility estimates, that deficits amount to close to $100 million per year (www.rti.org/impact/expanding-electricity-services-and-energy-access-in-ethiopia).

On the other hand, a plethora of empirical studies have examined the determinants of the quantity of electricity consumed and have considered electricity price, income, prices of other energy sources, prices of household appliances, and household socio-economic characteristics, among other factors (e.g.Ye*et al*., 2018; Shi*et al*., 2012;Filippini, 1999). For example, Ye*et al*. (2018) and Shi *et al*. (2012) found that electricity price was one of the major determinants of electricity demand in South Africa and China, respectively. On the other hand, Filippini (1999) showed the modest responsiveness of electricity consumption to prices. Related studies have also examined the role that other socio-economic factors play in determining households' energy consumption behaviour. Household income is an important factor in electricity consumption, which tends to be a normal good (Kim, 2020; Ye *et al*., 2018; Louw *et al*., 2008). The determinants of electricity consumption may vary depending on the consumption level of households themselves. For example, Kim (2018) noted heterogeneity in terms of electricity consumption and in the factors affecting household electricity consumption, such as socio-demographic characteristics (e.g. age, income, employment type, family size, and education) and location, etc. among the lowest and highest consumer of electricity groups in Korea. Several household characteristics, ownership of appliances, and institutional factors, such as access to credit, were also included in the analysis, and the findings varied depending on the nature of the data, the area of study, and the approaches used (Kim, 2020; Ye*et al*., 2018; Louw*et al*., 2008; Filippini and Pachauri, 2004).

Prior empirical studies in Ethiopia have used aggregate time series data to assess electricity demand at the country level (for example, Guta *et al*., 2013; Gabreyohannes, 2010).[4]To our knowledge, no prior study in Ethiopia has examined the microeconomic determinants of electricity demand, however, nor the role of electric price change. An important contribution of this study, therefore, is to estimate the effect of an electricity price increase on household consumption. In addition, we examine the impacts on households' other energy behaviours, namely the use of alternative energy sources. We take advantage of the timing of the recent electricity pricing reform to examine these issues.

In particular, our analysis uses detailed household survey data collected before and after the first phase of the price reform, supplemented by longer term utility billing data. Thus, we are able to examine the effects of the utility's continuous revision of the tariff rate over time, as it endeavoured to better cover the production costs of electricity and expand access to unconnected parts of the country. The findings of this research will help policymakers, planners, and other relevant stakeholders gain an understanding of the effects of electricity price changes on households' behaviour, and particularly on their electricity consumption. As the price revisions continued through the end of 2021 and are also considered for the following years, the findings from this study may also inform the utility about the consequences of the final planned tariff adjustments on customer behaviour and may allow the necessary steps to be taken to achieve the goals and objectives set by the country. In addition, a better understanding of the factors affecting households' electricity consumption can provide useful insights for possible planning of future demand patterns and growth, and further interventions in the sector.

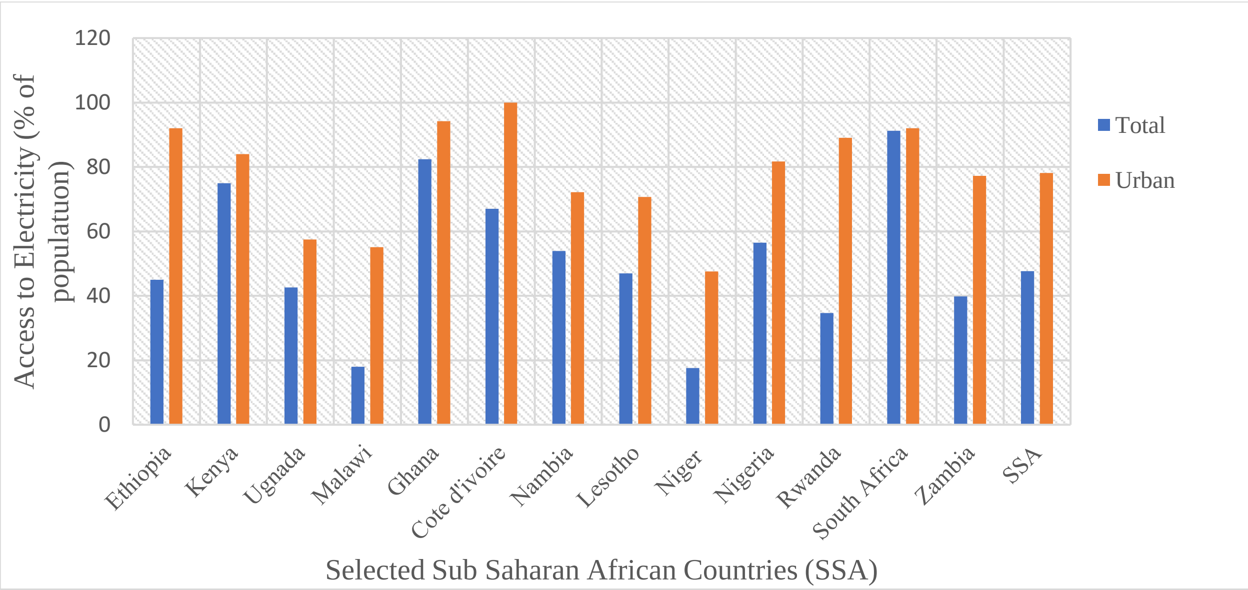
The paper is organised as follows. Section 2 discusses residential electricity consumption in Ethiopia. Section 3 presents the current tariff structure in Ethiopia. The data and sampling technique are discussed in Section 4. Section 5 presents the empirical strategy adopted to analyse the data. The empirical results are discussed in Section 6. We present conclusions and discuss policy implications in the final section.

2 Residential electricity access and consumption patterns in Ethiopia

In many developing countries, especially those in sub-Saharan Africa, the electrification rate remains very low (43%) (access rates overall and in urban areas for a sample of countries appear in Figure 1). Nonetheless, the consumption of electricity in Ethiopia has risen relatively quickly in the recent past, relative to other countries in the region (Figure 2). Indeed, the share of the population with access to electricity in Ethiopia increased from 13% in 2000 to48% in 2019, with 36% connected in rural areas, and 93% in urban areas, respectively (World Bank, 2020). The majority of the rural population thus still lacks access to any electricity, though access to electricity in urban Ethiopia is now higher than the average for Sub-Saharan African countries (78%).

[4]There are some studies which applied Computable General Equilibrium model to assess the impact of increase in electricity prices on various macroeconomic variables such as on gross domestic product, price level, energy consumption, poverty, etc. (Altman *et al*., 2009; Kohler*et al*., 2006; Van Heerden*et al*., 2008).

Figure 1. Access to electricity for selected Sub-Saharan African countries as of 2018



Despite these improvements, per capita electricity consumption is much lower in Ethiopia (132 kWh as of 2019) than in most other Sub-Saharan African countries, including Kenya, Zambia, and Ghana, which consumer 222, 798, and 471kWhper capita, respectively (Figure 2). This is mainly due to the fact that more than 80% of the country's population is rural and hence only a small proportion of the households are connected to the grid (Pappis *et al*., 2021). The per capita electricity consumption thus remains too low to achieve many national goals and objectives. This is because the low electricity consumption has made the return to investment on electricity infrastructure low. Given the historically low tariffs and consumption levels, households, on average, spend less than 5% of their total expenditure on basic electricity service (Padam *et al*., 2018), compared to more than 50% on food expenses, with increases in such expenditures only observed at the top of the income distribution (Figure 3).

Figure 2. Per capita electricity consumption for selected Sub-Saharan African countries

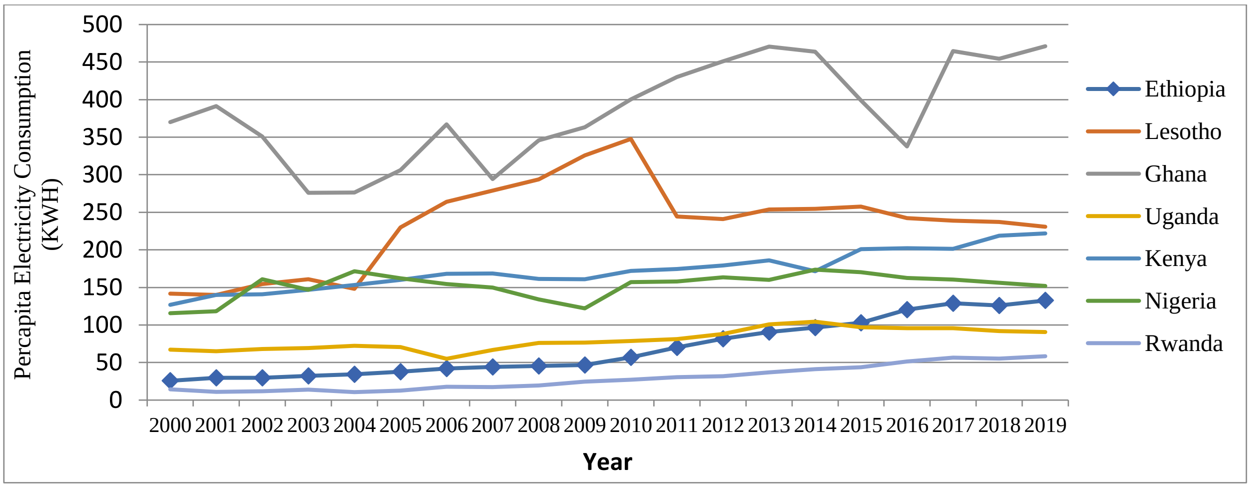
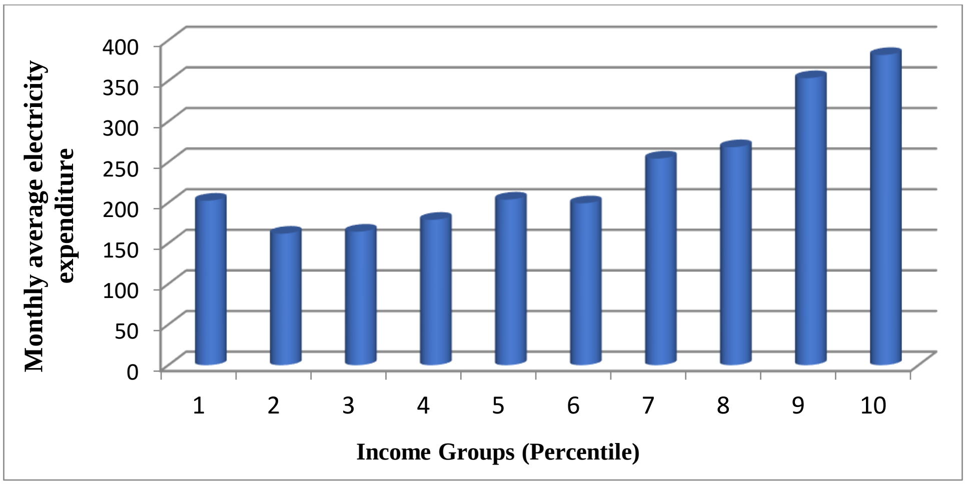
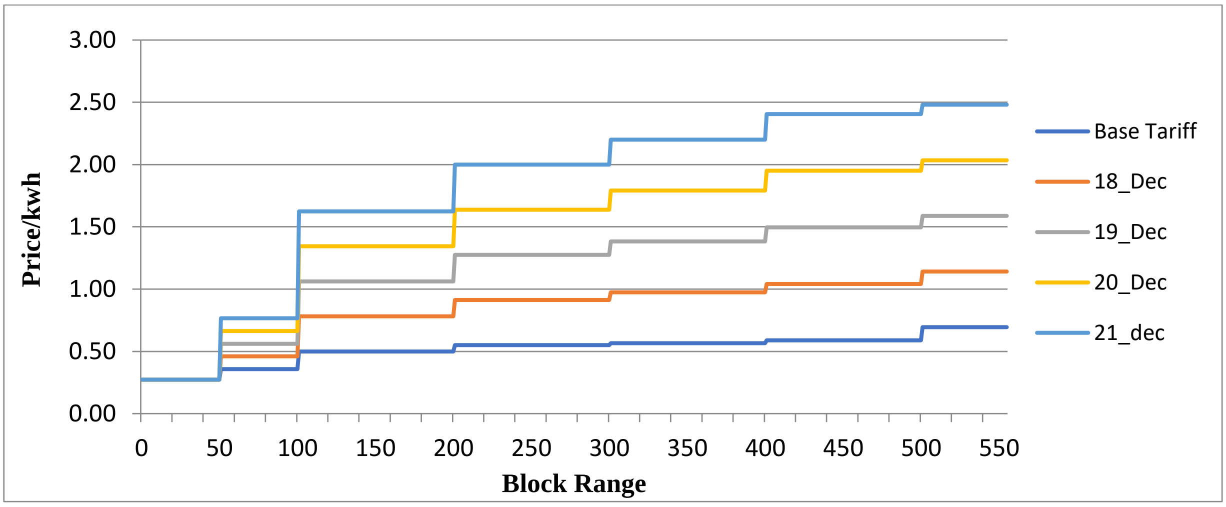


Figure 3. Households' monthly electricity expenditure by income group (Source: survey data 2016 and 2019)



Unpacking these patterns further, energy consumption patterns of households in Ethiopia are dominated by the use of electricity and biomass fuels. The former is mainly used for lighting and cooking by urban households. Yet biomass fuels, such as firewood and charcoal, are also still used for cooking and baking in urban Ethiopia. With the objective of promoting modern energy use for both lighting and cooking/baking purposes, Ethiopia is trying to increase investment in the electricity sector. The power sector faces serious financial challenges, however, stemming from low cost recovery, which is the primary motivation for the government's revising tariffs to attract investment and enhance the quality of service. Figure 4 shows the tariff changes being implemented over four phases stemming (2018–2021).

Figure 4. Base and proposed electricity tariff rate for residential customers



As shown in Figure 4, throughout the four phases, the tariff rate remains unchanged across the lifeline block for the lowest level of consumption (i.e., up to 50kWh per month). The tariff in the other blocks will all be raised incrementally over time. A more significant structural change, however, is that the new tariff structure which started in December 2018 is based on what is known as volume differentiated tariff (VDT) structure. The old tariff structure was based on an IBT structure, where the consumption in each block was charged according to the price specified for that block. With a VDT, however, the monthly electricity cost of the residential customer is obtained by multiplying the total monthly electricity consumption in kWh by the tariff per kWh for the block in which their final monthly consumption lies. For example, under the original IBT, customers consuming between 101 and 200 kWh in a month would have fallen in the third block and would have been charged ETB 0.273/kWh for the first 50 units of consumption, ETB 0.356/kWh for the next 50, and ETB 0.499/kWh for the remaining units of consumption prior to the 2018 tariff increase. Starting in December of 2018, however, they would have paid ETB 0.781/kWh for all units of consumption, an amount which would have increased to ETB 1.06/kWh, 1.34 ETB/kWh, and ETB 1.63/kWh in December 2019, 2020, and 2021, respectively. The highest group of customers is made up of those whose monthly consumption exceeds 500kWh/month. Accordingly, under the VDT, the tariffs per kWh for this group of customers were ETB 1.1410/kWh, ETB 1.5877/kWh, ETB 2.0343/kWh, and ETB 2.4810/kWh in December 2018, December 2019, December 2020, and December 2021, respectively. By the end of 2021, the rate for a customer just hitting the final block with 501 kWh/month of consumption would have increased by about 491% relative to the baseline IBT tariff rate (i.e.an average tariff of ETB 0.505/kWh).

If a consumer passes the VDT threshold, it will lead to a much higher cost increase compared to an IBT structure. Theoretically, this may create an incentive for the consumer to 'bunch' just below the VDT threshold (Ore *et al*., 2018). It is still an empirical question, however, whether this occurs. Ito (2014) did not find evidence for 'bunching' due to the tendency of electricity consumers to adjust their demand based on expected average price rather than marginal price.

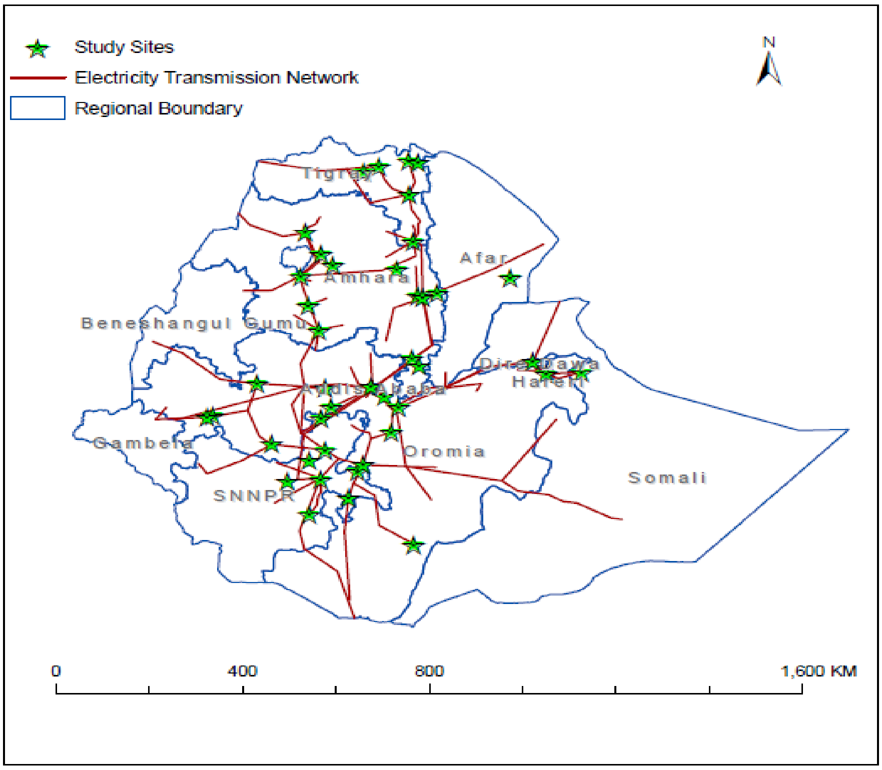
3 Data and sampling

Our data comes from the nationally representative Multi-Tier Framework (MTF) household survey for Ethiopia; this was first conducted in 2016 (World Bank, 2018),[5] and then repeated within the urban sub-sample only in 2019. The original survey used the 2007 National Population and Housing Census, conducted by the Ethiopian Central Statistical Agency, as a sampling frame. The 2007 Census consisted of 86,825 enumeration areas (17,363urban and 69,462 rural) spread across the country, with each enumeration area comprising 150–200 households (Central Statistical Agency, 2012).[6] The first round MTF survey considered the entire population residing in non-institutional dwellings, stratified via two designations: urban/rural; and electrified/non-electrified. In the first stage of sampling, a total of 433 enumeration areas were randomly selected from all regions in the country, stratified by means of these two conditions. Following the selection of enumeration areas, in the second stage, households within the retained locations were selected using a systematic random sampling technique. In all enumeration areas, except for 24 oversampled enumeration areas in Addis Ababa, 12 households were enrolled; in contrast, 20 households were chosen from those in Addis Ababa. A total of 5,469 households were selected.

For the purposes of this study, the first-round sample was used as the basis for construction of the second-round survey, which focuses exclusively on major urban enumeration areas. All sampled households in Addis Ababa that were enrolled in the first round MTF survey were again targeted in the second-round survey. All major towns from seven regional states and two city administrations (Addis Ababa and Dire Dawa) which were included in the first round MTF survey, except urban areas of Benishangul-Gumz and Gambella,[7] were also included in the second-round survey. In addition, most small towns that were surveyed in the first round, except those that are relatively inaccessible, were again included. Thus, a total of 1,182 households from Addis Ababa (54% of the full sample), and 1,010(46%) from other urban areas in regional states and one administrative city (Dire Dawa) (2,192 in all) were interviewed in the second-round survey. In other words, over 50% of the urban households surveyed in 2016 were included and were successfully revisited in 2019.Overall, our study covers most major cities of Ethiopia.[8]The locations of the major cities included in the sample are shown in Figure 5 below.

[5]Details on the survey and related information can be found at: https://datacatalog.worldbank.org/dataset/ethiopia-multi-tier-framework-mtf-survey-2018.
[6]Padam *et al*. (2018) provide details on the sampling procedures used in the first round of the MTF.
[7]The sample sites to be included in the second-round survey were chosen based on certain criteria, such as accessibility, security, and budget constraints. As a result, we omitted these two regions and some small towns in other regions.
[8]This is slightly larger than the share of the population of Addis Ababa in the total population of cities included in the sample (approximately 41%).

Figure 5. Map showing major study sites included in the sample



The household survey was administered from August to October 2019 via face-to-face interactions and using computer-assisted personal interviews. It was carried out by a group of 35 well-trained and experienced fieldworkers, consisting of 30 enumerators working under the close supervision of five supervisors. The authors were responsible for monitoring the progress of the field survey. Before the main survey, pilot tests were carried out to understand the situation regarding electricity. The survey questionnaire contains, among others, detailed information on household socio-demographic characteristics, sources of energy, perception on the current electricity tariff and fuel consumption, use of appliances, and cooking behaviour.

4 Methodology

We develop a simple theoretical model that assumes that the demand for electricity is derived from the demand for energy and the services that energy use provides, including, for example, cooking of food and heating of water by operating domestic devices, such as heaters and stoves, and the use of other home appliances such as televisions, etc.(Carter *et al*., 2012; Louw *et al*., 2008; Filippini and Pachauri, 2004).The household utility function incorporating the household's electricity demand can be expressed as:

$$U = u(x\{E, A, F\}, y, z) \qquad (1)$$

Subject to: $I < p_x x + p_y y$

where x represents the energy services consumed by the household, E represents electricity, A represents the stock of appliances operated, F represents the set of alternative fuels consumed by the household, y indicates the other goods and services consumed by the household, and z represents the tastes and preferences of the household. In the budget constraint, I is the income of the household, while p_x and p_y are the prices of energy services and the prices of other goods and services consumed, respectively. The household's objective is to maximise utility subject to this budget constraint. The Lagrangian function can then be formulated as follows:

$$L = u(x\{E, A, F\}, y, z) - \lambda(p_x x + p_y y - I) \qquad (2)$$

We can derive the first order conditions from Equation 2. These in turn can be rearranged to yield the Marshallian demand function for energy services, which is a function of prices, income, and other household characteristics (Equation 3). The stochastic term ε represents other factors that may have influence on the demand that are unobservable to the researcher:

$$x = x^*(p_x, I, z, \varepsilon) \qquad (3)$$

As described above, the electricity tariff was increased and modified in structure starting in December 2018, and included a gradual phased increase in electricity prices every year through the end of 2021. The main outcome variable in this study is household electricity consumption behaviour, measured in kWh. In addition, we consider other outcome variables such as expenditure on biomass fuels and liquefied petroleum gas (LPG). To cleanly estimate the causal effect of the tariff change, a random or 'as good as random' assignment of the tariff change to households would be necessary. However, in Ethiopia over this period, the tariff change was implemented among all electricity customers in the country simultaneously, which makes it difficult to specify a suitable control group for the impact estimation. Because of this, we rely on an event study regression specification. It requires pre- and post-event data on the outcome and other control variables. This study used a four-year period of monthly pre-reform electricity consumption, and a two-year period of monthly post-reform electricity consumption data.

The event study regression method compares outcomes fora given household before and after the treatment (reform). The event study regression method assumes that there are no systematic changes over time, except for the treatment (reform). In this study, to control for other changes that affect the household overtime, we include time-varying household socio-economic characteristics. Finally, a fixed effect regression method is applied to avoid the biasing of the results by time-invariant, unobserved household characteristics. The event study regression model with controls and household fixed effects is presented as follows.

$$EC_{it} = \alpha + \beta post_t + \theta X_{it} + \gamma_i + \varepsilon_{it},(4)$$

where EC_{it} is household *i's* monthly electricity consumption in kWh at a particular month and year, $post_t$ is an indicator variable that takes a value of 1for periods after the reform (2019 or 2020) and 0 for the pre-reform periods (2015, 2016, 2017, and 2018), X isa vector of other socio-economic time-varying characteristics of households, γ_i is a household fixed effect that absorbs time-invariant unobserved household characteristics, and ε_{it}isthe error term. The coefficient βcaptures the change in electricity consumption across the pre- to post-tariff reform periods.

Further, a standard fixed effect and an instrumental variable (IV)first fixed effect equation was used to examine the effect of electricity price on households' electricity consumption.

$$EC_{it} = \delta + \tau(averge\_price)_{it} + \theta X_{it} + \gamma_i + \varepsilon_{it}(5)$$

Where average price is the average monthly price variable computed from the total electricity bill and total quantity of electricity consumed (measured in kWh), and all other variables are as explained above. The main purpose of this estimation is to show the general effect of price on electricity consumption without referring to a particular period. A problem when estimating the standard price equation is that the price variable is endogenous, i.e., the price variables are functions of consumption, and hence are correlated with unobserved demand shocks. Although the fixed effect controls for the effect of time-invariant, unobserved household factors, this does not control for the effect of time-varying, unobserved shocks. The IV regression method deals with these unobservables.

Previous studies used baseline and mid-period prices as an instrument for current prices (e.g., Blomquist and Selin,2010; Ito, 2014). Ito (2014) showed that, in a difference equation, baseline prices are not good instruments because baseline consumption is correlated with baseline unobservables (as mean reversion of consumption creates negative correlation). Because of this, with monthly data, midway or mid-period prices are preferred (Ito, 2014). Following this, using a monthly data, we used midway average prices as instruments.

In addition to the effect of the tariff reform on electricity consumption, we also examine its effect on the consumption of alternative energy sources, such biomass and LPG. This enables us to estimate the substitution effect of the tariff increase on the consumption of alternative fuel sources. The latter would have implications for household coping costs (time and money spent on alternatives), health and well-being, and environmental quality outcomes, namely forest degradation and climate-forcing emissions (Jeuland and Pattanayak, 2012; Jeuland *et al*., 2018).

5 Descriptive statistics

This section discusses the descriptive statistics for the household sample, including socio-economic characteristics, the consumption of electricity before and after the reform, and the difference in consumption between Addis Ababa and regional towns.

Table1. Socio-economic characteristics of sample households

	2016		2019	
Variables	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**
Monthly electricity consumption (kWh)	183.17	143.07	207.21	149.56
Monthly electricity expenditure (ETB)	108.73	104.28	205.24	130.45
Average price (ETB/KWh)	0.83	2.22	1.20	1.74
Metered households (=1 if HH has meter)	0.90	0.30	0.91	0.29
Pre-paid meter (1=yes, 0=no)	0.02	0.15	0.49	0.50
Percapita consumption	1081.76	1018.78	1767.92	2685.59
Age of household head	51.19	15.08	53.08	14.61
Unemployed or pensioned	0.28	0.42	0.27	0.39
Casual workers	0.24	0.42	0.18	0.38
Hired professional workers	0.27	0.44	0.33	0.47
Work in own business/self-employed	0.22	0.41	0.23	0.42
Married households (1=married, 0=not married)	0.57	0.50	0.63	0.48
Household size	4.52	1.95	4.77	2.04
Number of households sharing the dwelling	0.68	2.39	0.28	0.83
Dwelling ownership (1=yes, 0=no)	1.56	0.50	1.41	0.49
Number of households	1896		1844	

Starting with the overall households' socio-economic characteristics, Table 1 shows the descriptive statistics for the outcome and control variables used in the regression analysis. As shown, the mean values of several variables change across the two surveys time periods. For example, monthly mean electricity expenditure almost doubled in the second wave following the increase in electricity price. It is not only electricity expenditure that increases post-reform; households also, on average, increase the quantity of electricity consumed. Other variables that show significant increases include the share of households with pre-paid meter and household per capita income.

One of the strategies that households could use to adapt the increase in electricity price is to use energy efficient electric appliances. Energy efficient light bulbs are relatively cheap and are readily available to households, and can be obtained in a relatively short period of time. A question was added to capture the purchase of such devices in the second wave of the survey. Table2 shows the percentage of households that use energy efficient light bulbs and the percentage of households which changed their bulbs after the first tariff increase. The table shows that about 82% of the sample households use energy efficient bulbs, of which 53% changed to these bulbs after the tariff increase.

Table2. Households' use of energy efficient bulbs in 2019

Bulb type	Percentage
Incandescent	14.43
Light-emitting diode/compact fluorescent lamp (energy efficient bulbs)	82.6
Other	0.09
Both	2.88
Households buy and have started to use an energy efficient bulb after the first tariff hike (1=yes, 0=no)	53

We analysed the trend in outcome variables in detail to see the extent of the impact of the new tariff, using monthly data obtained from the Ethiopian Electric Utility. Importantly, the monthly data obtained from the utility may not always correspond toa single month of consumption. In some months, no consumption is reported, and this situation is most common among customers with pre-paid meters. Such households often make payments that cover several months of consumption at a single time. For post-paid meter customers, gaps occur when the assigned meter reader does not visit a customer's house and the consumption report is not sent to the utility on time. To deal with such data gaps and obtain the monthly consumption corresponding to the gap between bills, we take the difference between the two nearest post-paid readings (pre-paid recharges), and divide by the number of days between the readings (recharges). Because this may introduce non-random measurement errors when consumption is varying across months, in robustness checks, we also sum household electricity consumption over six months among all households, and divide this by six to get comparable smoothed measures of average monthly consumption for the entire sample.

Figure6. Monthly electricity consumption (monthly consumption data)

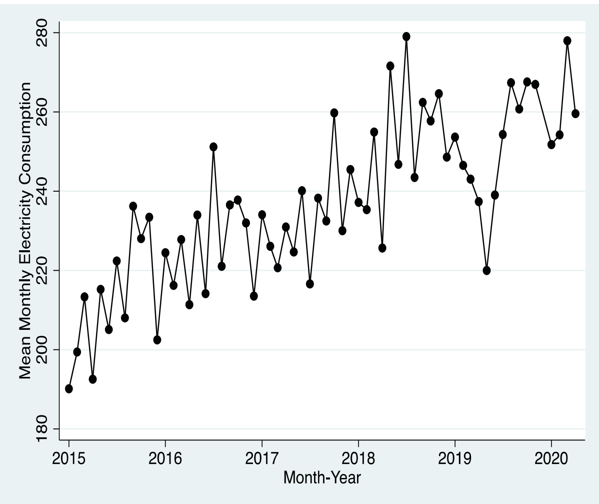
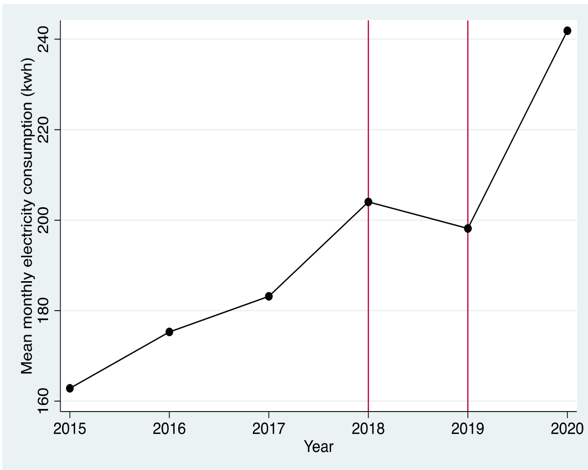


Figure7. Mean monthly electricity consumption (average calculated from semi-annual consumption)



Figures 6 and 7 show the monthly electricity consumption and average monthly electricity consumption obtained from this semi-annual electricity consumption aggregation, respectively. The two graphs show similar trends. Overall, the monthly and average monthly consumption trend shows an increase in households' electricity consumption over time. However, between the end of 2018 and the middle of 2019, there is a brief drop in electricity consumption. This coincides with the first increment of the electricity price hike (which occurred in December 2018 but was prominently aired in the news in the several months before December). Households apparently initially responded to the increase in electricity price by reducing consumption. However, this initial downward response did not persist. By the middle of 2019, the consumption of electricity had rebounded strongly. Households may have had adapted to the increase in prices and returned to their long-term trend of increasing consumption, after realising that the benefits of maintaining pre-hike levels of consumption outweighed the additional costs.

Figure8. Mean monthly electricity use (consumption) and expenditure

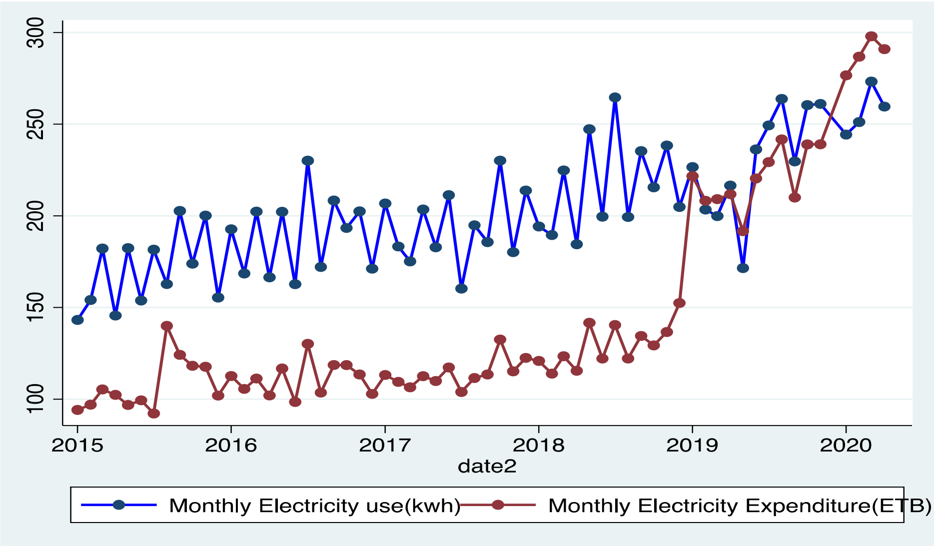
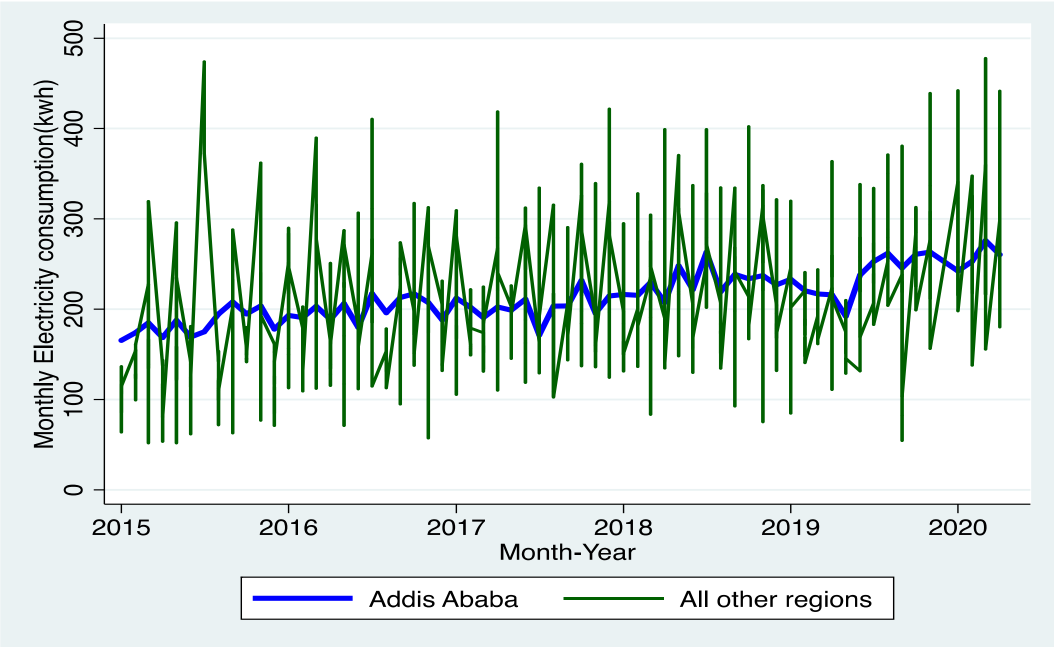


Figure8shows monthly electricity use (consumption) and expenditure trends over the period 2015–2020. The graph shows that until end of 2018(before the tariff reform), both quantities were increasing at a slow rate. Household expenditure was below ETB 150/month over the entire period. Following the reform in 2019, expenditure immediately nearly doubled to more than ETB 200/month, and then began to increase again in mid-2019, when electricity consumption returned to its pre-tariff hike level, before jumping again in late 2019 as the second electricity price hike occurred. Electricity consumption (use), on the other hand, dipped downward slightly in early 2019, and then returned to the long-term increasing trend by the beginning of 2020, reaching levels more than60% higher than in 2015. It has to be noted that the relationship between expenditure and consumption depends on the price elasticity of demand.[9]

Figure9compares the electricity consumption between Addis Ababa and the other major regional towns in the sample. The figure shows that there is much higher variability in regions other than in Addis Ababa. This could be related to electricity reliability problems in these regions. Since Addis Ababa is the capital and a diplomatic seat, electricity blackouts are less common than in other regions. Both figures show a downward trend during the initial period following the tariff hike (at the end of 2018 and the beginning of 2019), followed by a return to the long-term increasing trend in 2020.

[9]That is, for an inelastic demand expenditure rises as price continue to increase, but vice versa for an elastic demand.

Figure 9. Mean monthly electricity consumption in Addis Ababa and regional towns



If the tariff increases led to declines in electricity consumption, there might be an additional effect of households shifting to other fuel sources to mitigate the price impact. The degree of actual fuel switching will vary depending on the service demand for electricity, with for example biomass and charcoal being alternatives to electricity in cooking.[10] Figures 10 and 11show the average monthly expenditure for biomass and charcoal, respectively.[11] Biomass expenditure includes expenditure for wood and dung.

Figure 10. Monthly biomass expenditure

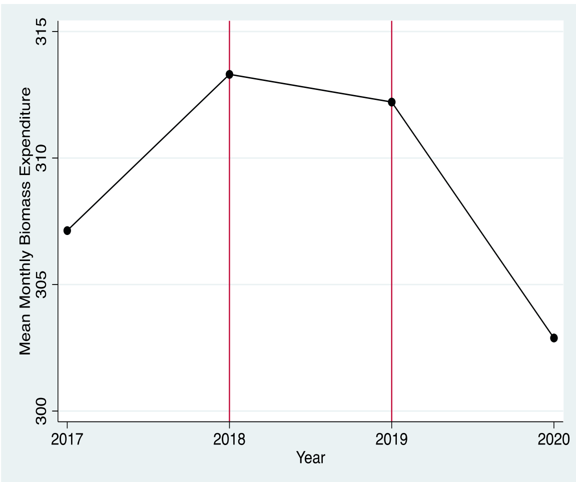
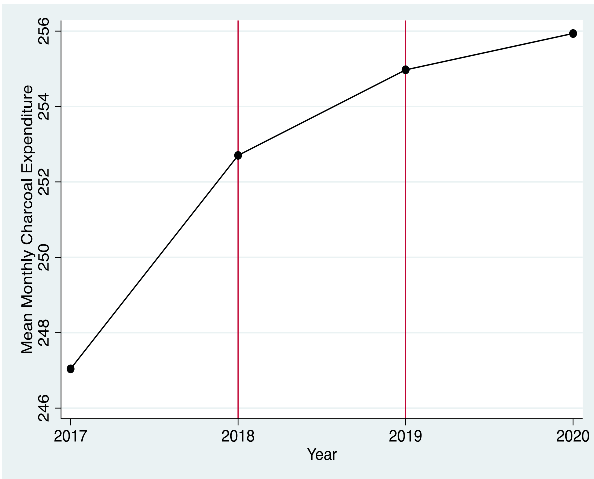


Figure 11. Monthly charcoal expenditure



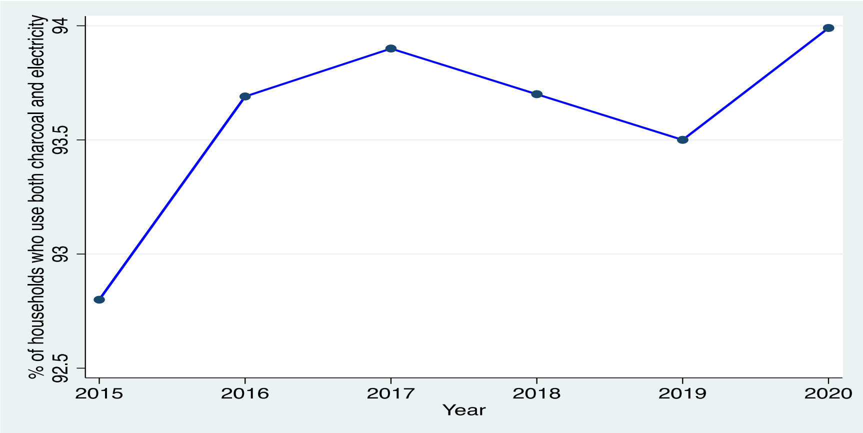
The trend in biomass expenditure has an inverted U-shaped curve, with an increase in consumption before the tariff and an almost constant consumption during the initial period following the tariff increase, followed by a sharp decrease in consumption afterwards. Putting these trends together, it would appear that households mostly use both biomass fuels and electricity, depending on the type of activity (i.e., whether it is for cooking, lighting, entertainment, etc.). Since 2019, however, this situation has changed as households have reduced their consumption of biomass fuels (electricity consumption continues

[10]Electricity is frequently used in Ethiopia for cooking and baking. Charcoal is an alternative for cooking only, while other biomass fuels, such as firewood and leaves, can be used for both cooking and baking. Measures other than fuel switching might also be considered to cope up with the increase in electricity tariff (see the paper by Hassan *et al*., 2021). Note that residential customers in Ethiopia rarely use generators as a back-up source of power.

[11]There were insufficient data points for LPG to generate a similar graph.

to rise). In contrast, charcoal consumption has a similar increasing trend before and after the tariff increase. Consumption was increasing before and after the tariff change, and perhaps began to level towards off towards the end of the period. The increase in both electricity and charcoal consumption before the tariff change implies that households use both of these fuels concurrently, perhaps for different activities (Alem *et al*.,2014). For example, households may use charcoal for making coffee and tea, and cooking some types of food, while using electricity for lighting, baking, entertainment, refrigeration, etc. In the years between 2018 and 2019(the period enveloping the initial tariff change), when electricity consumption decreased, charcoal consumption continued to rise; some households may have compensated for lower electricity consumption by increasing use of charcoal.[12]In fact, in this period, Figure12shows a declining trend in the percentage of households which use both charcoal and electricity. After 2019, both charcoal and electricity return to their increasing trends, suggesting renewed complementarity in these fuels.

Figure12.Percentage of households using both charcoal and electricity



Tariff change may have impacted income groups differently. In fact, studies from other countries showed that increases in electricity price have a negative impact more on poor households than on middle-income or rich households (Waddams and Pham,2009). On the contrary, although this is based on descriptive results (Table3), this study result showed that households below the median income group did in fact increase their consumption after the tariff change. This can be explained by the fact that electricity prices were not changed for the very poor (consumption at or below 50kWhper month) or smaller increment for the poor in general. There is no significant change in the consumption for median and above median income households, although consumption reduced slightly after the change.

Table3. Households' electricity consumption by income group before and after the tariff reform

Income group	Mean before tariff change	Sd. err.	Mean after tariff change	Sd. err.	Mean diff.	Sd. err.	t-value
Below the median income	199.88	1.78	210.76	3.31	-10.89	3.67	-2.96***
Median income (=ETB 3000)	214.52	5.32	207.22	7.27	7.30	9.20	0.79
Above the median income	231.41	1.88	229.42	2.76	1.99	3.38	0.59

[12]As described in Hassan et al. (2021), households pursue different measures to cope with increases in the tariff rate. These are: reducing the frequency of cooking and baking; and turning off appliances when not in use. A small proportion of sampled households responded that they reduced the number of light bulbs (2.9%)and shifted to other fuels, such as biomass (11%).

6 Econometric results

The effect of the revised tariff on electricity consumption is estimated econometrically using an event study fixed effect regression method. In the event study, a dummy time variable is the key explanatory variable. Its coefficient shows the extent of change of the dependent variable (electricity consumption) as a result of the intervention (tariff change), provided that the time variable is uncorrelated with the error term (i.e. absence of systemic change over time except for treatment). We minimise the effect of any systemic changes overtime by including explanatory variables that are correlated with the time dummy variable. Table4shows fixed effect regression results of the change in household's socio-economic characteristics pre- and post-reform (a regression of time dummy on socio-economic characteristics of the households). The results show that there is a change in per capita expenditure, the electricity meter type, and the age of the households over time. We control for these and other potentially time-varying variables in the event specification model.

Table4. Fixed effect regression of change in households' socio-economic characteristics pre- and post-tariff change period (dependent variable=time dummy) (=1 post-tariff, =0 pre-tariff periods)

Variables	Coef.	Std. err.	T
Meter sharing (1=yes,0=no)	-0.212***	0.036	-5.86
Per capita expenditure	0.157***	0.025	6.33
Age	1.014***	0.169	6.01
Wife years of education (Log)	0.030	0.031	0.96
Pre-paid meter (1=yes, 0=no)	0.284***	0.079	3.57
Casual workers	-0.077	0.069	-1.13
Hired professional workers	-0.085	0.068	-1.26
Work in own business	-0.076	0.061	-1.24
Married households (=1 married, 0=not married)	-0.073	0.315	-0.23
Number of children (Log)	-0.059	0.068	-0.86
Household size	0.210**	0.096	2.19
Number of households sharing the dwelling (Log)	-0.027	0.037	-0.73
Dwelling ownership (1=yes,0=no)	0.033	0.062	0.54
Constant	-4.982***	0.747	-6.67
Number of households	1844		
R-squared	0.080		

***, **, * refers to significance at 1%, 5%, and 10% levels, respectively.

The result of the event study regression model on the effect of tariff change on households' electricity consumption is shown in Table5(Panels A and B). Panel B provides the result when the time dummy (the post-tariff reform period) is interacted with a pre-paid meter indicator variable (pre-paid meter), while Panel A is the model without this interaction. The rationale for including this interaction is that households with different meter types may have very distinct awareness and responses to the tariff change. In particular, those with pre-paid meter owners can read their expenditures (remaining recharged amount) on the meter screen as they are consuming electricity, while all but the most fastidious post-paid meter owners typically receive this information only at the end of the month.

Table5: Event study fixed effect regression result of effect of tariff reform on households' electricity consumption (kWh) (dependent variable=monthly electricity consumption in kWh)

Variables	Panel A		Panel B	
	Coef.	**Se.**	**Coef.**	**Se.**
Post-tariff reform period (=1 for post-tariff reform periods, =0 for pre-reform periods)$	-1.551	1.444	5.122***	1.818
Has own meter (1=Yes, 0=No)	-24.192	31.587	-22.287	31.574
Pre-paid meter (1=yes, 0=no)	1.425	4.831	6.253	4.895
Pre-paid meter #post-tariff reform			-18.063***	2.995
Percapita consumption	0.0005*	0.0003	0.0005	0.00041
Age of the household head	0.411***	0.124	0.388***	0.124
Causal workers	1.433	3.014	1.52	3.013
Hired professional workers	3.178	3.369	2.992	3.367
Work in own business	0.46	3.24	0.36	3.239
Married households (=1 married, 0=not married)	13.234***	3.321	13.639***	3.32
Household size	1.046*	0.595	1.129*	0.595
Number of households sharing the dwelling	0.024	0.476	0.122	0.476
Dwelling ownership (1=yes, 0=no)	-6.117**	2.987	-5.954**	2.986
Constant	203.565***	32.741	202.533***	32.726
Observations	39,195		39,195	
R-squared	0.14		0.15	
Number of households	1,844		1,844	

*** p<0.01, ** p<0.05, * p<0.1, $ pre-reform periods refers to 2015,2016, 2017 and 2018 and post-reform period refers to 2019 and 2020

As discussed in the descriptive statistics section, the monthly data obtained from the Ethiopian Electric Utility contains gaps; we adjust this by taking the difference between the two nearest post-paid readings (pre-paid recharges), and divide by the number of days between the readings (recharges). The result in Table5accounts for this adjustment. As shown, the coefficient for the post-hike indicator variable has a very different sign and significance in Panels A and B. In Panel A, the coefficient of the time dummy is negative and statistically indistinguishable from zero, suggesting that the tariff increase had no effect on electricity consumption. The negative sign is suggestive of a slight declining trend, which is perhaps due to the short-term decline observed in Figure6.The lack of precision in the coefficient estimate likely reflects the fact that this declining trend is counterbalanced by an increasing trend starting in mid-2019, such that the magnitude of the overall change attributable to the tariff hike is no different from zero.

When the time dummy variable is interacted with the pre-paid meter owners, however, the result is substantively different. The coefficient on the post-reform indicator becomes positive and significant, while the interaction with pre-paid meter ownership is negative, large, and significant. The negative sign and significance of this interaction suggests that pre-paid customers did substantially reduce their consumption of electricity, by about 18kWh per month after the tariff reform, i.e., their monthly average consumption reduced from 225kWhper month before the reform to 207kWhafter the reform. On the contrary, the positive sign and the significance of the time dummy coefficient shows that overall average electricity consumption is higher in post-reform periods by about 5kWh per month. In terms of economic significance, a 5kWh/month increase is relatively small (it is equivalent to an amount of additional spending of about ETB 5 (or USD0.125) per month), and likely reflects only very minor electricity consumption increases.

As discussed in the above sections, the second way to adjust the data gaps obtained from utility was by calculating monthly average from the total of six months' electricity consumption. The results in Table2A (in the appendix) are based on this computation. The results of Panel B are consistent in both tables (Tables 5and 2A), i.e., pre-paid customers reduced their electricity consumption after the tariff reform and the overall average electricity consumption is essentially unchanged (increasing only slightly) in the post-reform periods. Consistent with these results, households also do not appear to significantly shift to other fuel sources such as biomass and LPG (Table3A in the appendix).

With respect to other variables, monthly electricity consumption is higher in households where the head is older. This may be because older households use older, less efficient appliances, or have accumulated more appliances (requiring more electricity).[13] We also find positive and significant relationships between electricity consumption and married status, and with larger household size. The result with larger household size is expected because larger households will have greater demand for energy for various purposes. Households which live in their own houses also consume less electricity than those who rent. This may have to do with how renters pay for electricity (i.e. in some cases rent is included in the house rent; others pay fixed amount regardless of use), as well as the reduced incentives for investment in energy efficient appliances among such households.

We further analyse the relation between price and electricity consumption using standard fixed effect and IV fixed effect approaches, using the midway price as an instrument. Statistically, the relevance of the instrument is tested using a first stage regression. Table6shows the first stage result of IV regression. This result shows that the midway price is significantly related to the logged average price.

Table 6. First stage regression of the IV-fixated effect regression (log midway average price as instrument) (dependent variable average price)

Variables	Coef.	Se.
Log (midway price)	0.011***	0.003
Has own meter (1=yes, 0=no)	-0.057	0.089
Pre-paid meter (1=yes, 0=no)	0.051***	0.007
Percapita consumption	0.000**	0.000
Age	0.000	0.000
Causal workers	0.004	0.007
Hired professional workers	0.025***	0.007
Work in own business	0.024***	0.007
Married households (=1 married, 0=not married)	-0.002	0.006
Household size (Log)	-0.001	0.001
Number of households sharing the dwelling (Log)	-0.006***	0.001
Dwelling ownership (1=yes, 0=no)	-0.020***	0.006
Months	Yes	
Constant	0.664***	0.091
Observations	38,755	
Number of households	1,844	

Table7 is the standard fixed effect and IV regression result for the effect of electricity price on electricity consumption. Panel A is the result for the standard fixed effect result, while Panel B is the IV fixed effect. Consistent with prior work that consumers respond to the average price (Ito, 2014; Cardenas and Whittington, 2015), the results in both panels show that the average price is negative and statistically significant. The IV and standard fixed effects models are different in terms of the magnitude of response, however. The standard fixed effect overestimates the magnitude of the response by about 45% in absolute terms. Thus, based on the IV-result, a 1% increase in price is related to a 0.38% decrease in electricity consumption, which implies that electricity demand is price inelastic in urban Ethiopia. For rural households, which are not part of the study, outcomes might be different. As rural households depend on freely available biomass energy sources, electricity demand may be more price elastic. In other words, a slight increase in the electricity price, making electricity more expensive, might induce poorer rural households to reduce electricity consumption more significantly than it does urban ones.

[13] Our data limits us to control use energy-efficient appliances.

Table 7. Fixed effect and IV regression of the effect of price on electricity consumption (dependent variable log monthly electricity consumption (in kWh)) (monthly data)

	Panel A		Panel B	
Variables	Coef.	Se.	Coef.	Se.
Log average price	-0.695***	0.013	-0.386**	0.155
Controls	YES		YES	
Monthly time period	YES		YES	
Constant	4.940***	0.241	4.923***	0.31
Observations	39,195		9,087	
R-squared	0.18		0.143	
Number of HH_ID_N	1,844		1,844	

*** p<0.01, ** p<0.05, * p<0.1. Panel A is simple fixed effect regression, while Panel B is an instrument regression using midway monthly price, i.e., price level at t-6 as instrument.

The results in Table7 are consistent with the event regression results in Table4. The inelastic price estimate means that households have low sensitivity to the price increase.[14] Hence, the insignificant impact of the reform is partly due to the price inelastic demand.

7 Conclusions and policy implications

In Ethiopia, prior to late 2018, the electricity price had not been changed for more than a decade, despite the devaluation of ETB against the US dollar and an overall sharp increase in production and consumption prices of other types of goods and services in the country. Electricity prices in the country were among the lowest in sub-Saharan Africa, and this situation had created an immense financial burden for the public-owned utility, and therefore also the government. Financial constraints had long hindered the utility's ability to provide quality electricity service to its customers, and frequent power outages became the norm for electrified households and enterprises.

Recognising these problems, the Ethiopian Electric Utility, in cooperation with Ethiopian Energy Authority, introduced a new tariff structure and raised rates starting in December 2018.Customers consuming fewer than 50 kWh of electricity per month (presumably low-income households with low electricity needs) did not experience a change in the electricity price. Households or firms that consumed more electricity faced increasingly higher costs of electricity per kWh following the reform.

This paper examined the effect of the new tariff on urban households' electricity consumption, using household panel survey data and six years of electricity consumption data from the utility company. For the baseline, we used the Ethiopian MTF (the MTF of measurement of electricity access) household survey data, collected in 2016/2017, well before the tariff reform. The MTF collected data from about 4,000 urban and rural households, about half of whom were in urban areas. Because most rural households do not have access to electricity, our study focused on urban areas, and a follow-up survey was conducted among most of the original urban MTF households in 2019, shortly after the first phase of the tariff hike.

In descriptive analyses, we found that electricity consumption decreased immediately after the introduction of tariff; however, this effect did not persist, and the consumption trend soon reverted to the pre-reform trajectory by the end of first year. This suggests that the effect of the tariff increase was short-lived, even as it increased electricity expenditures (and revenues for the utility) substantially.

An event study, fixed effect regression approach was then used to investigate the effect of the tariff change empirically. Using this method, we found that pre-paid customers reduced their consumption of electricity by about 18kWh, which is equivalent to 8% of their monthly electricity expenditure. The pre-paid customers may have reduced their consumption because of their access to their daily consumption information, i.e., their screen on the meter can show their left-over charges and can respond

[14] The sample size is not good enough to create such stratification. But we can show this descriptively.

to changes in consumption accordingly. However, electricity consumption in the overall sample appeared unchanged in the post-reform period. This suggests that the increased price was not large enough to reduce electricity consumption significantly among all customers, which is also consistent with the inelastic price elasticity of demand for electricity obtained from an IV regression. Analysis of the effect of the tariff reform on the consumption of alternative fuels, mainly biomass fuels, further revealed that the electricity price increase had no impact on expenditure on these alternatives. Households did not appear to substitute other fuels for electricity following the tariff increase.

One policy implication of this study is that governments that are seeking to raise revenue without substantially reducing households' electricity consumption may be able to achieve this goal with modest gradual increases, such as those deployed in Ethiopia. This is likely to be true, especially when electricity is substantially under-priced. In this case, the additional revenue obtained from the increased tariffs can be used to improve service and enhance access to electricity in other parts of the country. Therefore, the results of this study point to potential ways out of the low cost recovery–low quality electricity trap.

It needs to be noted that this study looked only at the short-run impact of the electricity tariff reform and short-term price elasticity. The long-run impact could be different. This study also did not analyse the impact among different household income groups (as the sample size is not large enough to create such a stratification) and the impact on other consumption goods. Further research on these issues is recommended.

References

Allcott, H. (2011) 'Rethinking real-time pricing', *Resource and Energy Economics* 33, pp. 820–842.

Alem, Y., Hassen, S.,and Kohlin, G. (2014)'Adoption and Dis-adoption of Electric Cookstove: Panel Data Evidence from Ethiopia', *Resource and Energy Economics* 38, pp.110–124.

Altman, M., Davies, R., Mather, A., Fleming, D., and Harris, H. (2009) 'The impact of electricity price increases and rationing on the South African economy',www.hsrc.ac.za/Research_Publication-21004.phtml[last accessed 23 November2011].

Blimpo, M.P., and Cosgrove-Davies, M. (2019) 'Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact. Africa Development Forum series', World Bank, Washington, DC. doi:10.1596/978-1-4648-1361-0.

Cardenas, H., and Whittington, D. (2019) 'The Consequences of Increasing Block Tariffs on the Distribution of Residential Electricity Subsidies in Addis Ababa, Ethiopia', *Energy Policy*128, pp.783–795.

Carter, A., Craigwell, R., and Moore, W. (2012) 'Price reform and household demand for electricity',*Journal of Policy Modelling* 34(2), pp. 242–252.

Filippini, M. and Pachauri, S. (2004) 'Elasticities of electricity demand in urban Indian households', *Energy Policy* 32(3), pp. 429–436.

Filippini, M. (1999) 'Swiss residential demand for electricity', *Applied Economics Letters* 6 (8), pp.533–538.

Flaig, G. (1990) 'Household production and the short and long-run demand for electricity', *Energy Economics* 12(2), pp. 116–121.

Freund, C.L., and Wallich, C.I. (1996) 'The Welfare Effects of Raising Household Energy Prices in Poland', *The Energy Journal* 17(1), pp. 53–77.

Gabreyohannes, E. (2010) 'A Nonlinear Approach to Modelling the Residential Electricity Consumption in Ethiopia', *Energy Economics* 32, pp. 515–523.

Guta, F., Beyene, A.D., and Ferede, T. (2015) 'The Residential Demand for Electricity in Ethiopia Environment for Development', Discussion Paper Series EfD DP 15-07.

Hafner, M., Tagliapietra, S., and de Strasser, L. 2018. 'Energy in Africa', Springer Briefs in Energy, https://doi.org/10.1007/978-3-319-92219-5_1.

Hassen, S., Seifemichael, R., and Anandarajah, A. (2021)'Household's investment in energy efficiency and coping strategies to electricity tariff increase', www.energyeconomicgrowth.org/publication/households-investment-energy-efficiency-and-coping-strategies-electricity-tariff [last accessed 28 February 2022]

Huenteler, J., Dobozi, I., Balabanyan, A., and Banerjee, S.G. (2017) 'Cost Recovery and Financial Viability of the Power Sector in Developing Countries: A Literature Review', World Bank Policy Research Working Paper 8287, Washington, DC.

IEA. (2020) *World Energy Outlook 2020*, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2020. [last accessed 27 February 2022]

Ito, K. (2014) 'Do Consumers Respond to Marginal or Average Price? Evidence from Nonlinear Electricity Pricing', *American Economic Review* 104(2), pp. 537–563.

Jessoe, K. and Rapson, D. (2014) 'Knowledge Is (Less) Power: Experimental Evidence from Residential Energy Use', *American Economic Review* 104(4), pp. 1417–38.

Jeuland, M. A., and Pattanayak, S. K. (2012) 'Benefits and costs of improved cookstoves: assessing the implications of variability in health, forest and climate impacts', *PLoS ONE* 7(2), p. e30338.

Jeuland, M., Soo, J. S. T., and Shindell, D. (2018) 'The need for policies to reduce the costs of cleaner cooking in low income settings: Implications from systematic analysis of costs and benefits', *Energy Policy* 121, pp. 275–285.

Kim, M.J. (2018) 'Characteristics and determinants by electricity consumption level of households in Korea', *Energy Reports* 4, pp. 70–76.

Klug, T.,*et al*. (2021) 'A Review of Impacts of Electricity Tariff Reform in Africa', draft report submitted to EEG.

Kohler, M. (2006) 'The economic impact of rising energy prices: a constraint on South Africa's growth and poverty reduction opportunities, 2006',www.tips.org.za/files/forum/2006/papers/KholerEconomicImpact.pdf[last accessed 24 September 2011].

Lin, B., and Liu. X. (2013) 'Electricity tariff reform and rebound effect of residential electricity consumption in China', *Energy* 59(15), pp.240–247.

Louw, K., Conradie, B., Howells, M., and Dekenah, M. (2008) 'Determinants of electricity demand for newly electrified low-income African households', *Energy Policy* 36, pp.2812–2818.

Ministry of Water, Irrigation and Electricity (2019) 'National Electrification Program 2.0: Integrated Planning for Universal Access', Addis Ababa, Ministry of Water, Irrigation, and Energy, Federal Democratic Republic of Ethiopia.

Ore, H., Antonio, M., Sánchez, L.A., Sousa, L.D., and Tornarolli, L. (eds) (2018) 'Fiscal and Welfare Impacts of Electricity Subsidies in Central America. Directions in Development', World Bank, Washington, DC. doi:10.1596/978-1-4648-1104-3.

Pappis, I., *et al*. (2021) 'Influence of Electrification Pathways in the Electricity Sector of Ethiopia – Policy Implications Linking Spatial Electrification Analysis and Medium to Long-Term Energy Planning', *Energies* 14, pp. 1209. https://doi.org/10.3390/en14041209.

Peter, C. R., and White, M.W. (2005) 'Household Electricity Demand, Revisited', *The Review of Economic Studies* 72(3), pp. 853–883.

Shi, G., Zheng, X., and Song, F. (2012) 'Estimating Elasticity for Residential Electricity Demand in China', *The Scientific World Journal* 12, pp. 1–6, doi:10.1100/2012/395629

Silva, P., Klytchnikova, I., and Radevic, D. (2009) 'Poverty and environmental impacts of electricity price reforms in Montenegro', *Utility Policy* 17, pp. 102–113.

Tayal, D., and Evers, U. (2018) 'Consumer preferences and electricity pricing reform in Western Australia', *Utilities Policy54*, pp. 115–124, https://doi.org/10.1016/j.jup.2018.08.008.

World Bank *(2020)* '*World Development Indicators*', The World Bank, Washington, DC.

Ye, Y., Koch, S.F., and Zhang, J. (2018) 'Determinants of household electricity consumption in South Africa', *Energy Economics* 75, pp. 120-133, https://doi.org/10.1016/j.eneco.2018.08.005

Zhang, F. (2011) 'Distributional Impact Analysis of the Energy Price Reform in Turkey', *WB Policy Research Working Paper 5831*. Washington, DC.

Waddams P.C., Pham, K. (2009) 'The impact of electricity market reform on consumers', *Utilities Policy* 17, pp. 43–48.

Van Heerden, J., Blignaut, J., and Jordaan, A. (2008) 'On the Real Exchange Rate Effects of Higher Electricity Prices in South Africa', University of Pretoria, *Working Paper Number 9*.

Annex

Price blocks

Existing tariff (until December 2018)			The new tariff reform (December 2018–December 2019)	
Tariff block	**Consumption (In kWh)**	**Tariff in ETB**	**Tariff block**	**Consumption (In kWh)**
1st block	0–50	0.273	1st block	Up to 50
2nd block	51–100	0.356	2nd block	Up to 100
3rd block	101–200	0.499	3rd block	Up to 200
4th block	201–300	0.550	4th block	Up to 300
5th block	301–400	0.566	5th block	Up to 400
6th block	401–500	0.588	6th block	Up to 500
7th block	>500	0.694	7th block	>500

Table2A. Event study, fixed effect regression result of effect of tariff reform on households' electricity consumption (kWh) (dependent variable) (using semi-annual electricity consumption data)

	Without interaction		With interaction	
Variables	**Coef.**	**Se.**	**Coef.**	**Se.**
Post-tariff reform period (=1 for post-tariff reform periods, =0 for pre-reform periods)$	3.537*	1.957	6.719***	2.407
Has own meter (1=Yes, 0=No)	-45.075	47.919	-44.024	47.908
Pre-paid meter (1=yes, 0=no)	1.975	7.011	4.741	7.114
Pre-paid meter#post-tariff reform			-9.387**	4.137
Percapita consumption	0.0005*	0.001	0.0005*	0.0003
Age	0.451**	0.179	0.437**	0.179
Causal workers	4.709	4.323	4.683	4.322
Hired professional workers	4.851	4.724	4.849	4.724
Work in own business	1.608	4.627	1.556	4.625
Married households (=1 married, 0=not married)	13.155***	4.825	13.395***	4.825
Household size (Log)	-1.805**	0.82	-1.848**	0.82
Number of households sharing the dwelling (Log)	0.69	0.685	0.738	0.685
Dwelling ownership (1=yes, 0=no)	-6.883	4.284	-6.801	4.283
Constant	217.656***	49.491	217.119***	49.478
Observations	9,087		9,087	
R-squared	0.14		0.15	
Number of HH_ID_N	1,844		1,844	

*** p<0.01, ** p<0.05, * p<0.1, $ pre-reform periods refers to 2015,2016, 2017 and 2018 and post-reform period refers to 2019 and 2020

Table 3A. Event study, fixed effect estimation of the effect of tariff reform on biomass and LPG expenditure

	Log biomass expenditure		Log LPG expenditure	
Variables	**Coef.**	**Se.**	**Coef.**	**Se.**
Post-tariff reform period (=1 for post-tariff reform periods, =0 for pre-reform periods)$	3.96	4.034	-0.026	0.315
Has own meter (1=Yes, 0=No)	0.135	8.451	-0.07	3.809
Pre-paid meter (1=yes, 0=no)	7.58	7.466	-0.07	0.564
Percapita consumption	0.002***	0.001	-0.000***	0
Age of the household head	-0.042	0.179	-0.004	0.014
Causal workers	6.499	4.326	-0.276	0.338
Hired professional workers	-2.018	4.789	0.209	0.376
Work in own business	4.88	4.614	0.059	0.362
Married households (=1 married, 0=not married)	-5.955	4.772	-0.143	0.38
Household size	0.092	0.813	0	0.065
Number of households sharing the dwelling	-0.17	0.672	0.015	0.054
Dwelling ownership (1=yes, 0=no)	4	4.26	0	0.337
2017.year	1.213	2.443	-0.650***	0.214
2018.year	4.762*	2.579	0	0.211
2019.year	0.806	3.299	-0.027	0.266
2016.year			0.208	0.214
Constant	323.454***	14.924	11.617***	3.932
Observations	3,971		5,379	
R-squared	0.011		0.008	
Number of households	1,844		1,843	
*** p<0.01, ** p<0.05, * p<0.1				

About the authors

Sied Hassen is a senior research fellow at Environment and Climate Research Center, based at the Policy Studies Institute in Ethiopia. He coordinates the energy research programme at the Centre. His research works emphasise the application of micro-econometrics and experimental economics to energy and agricultural economics. His current research focuses on applying econometrics tools on household- and firm-level energy consumption. Currently, he is actively working on a project entitled 'Impacts and Drivers of Policies for Electricity Access: Micro-and-Macroeconomic evidence from Ethiopia'.

Abebe D. Beyene is a senior research fellow at the Environment and Climate Research Center, based at the Policy Studies Institute in Ethiopia. His field of specialisation is environmental economics, which includes natural resource management, energy, climate change, and agriculture. Methodologically, he has a focus on applying micro-econometrics, such as cross-section and panel data econometrics. His current research focuses on household energy choice, improved cook stove use and REDD+, forest and people's livelihood, and adaptation to climate change, such as analysing the impact of sustainable land management practices.

Marc Jeuland is an Associate Professor in the Sanford School of Public Policy, with a joint appointment in the Duke Global Health Institute. His research interests include non-market valuation, water and sanitation, environmental health, energy poverty and transitions, transboundary water resource planning and management, and the impacts and economics of climate change. His recent research includes work to understand the economic implications of climate change for water resources projects on transboundary river systems, a range of primary data collection projects related to the analysis of the adoption of technology improving environmental health, and analysis of the costs and benefits of environmental health interventions in developing countries.

Alemu Mekonnen is a professor of economics at the department of Economics of Addis Ababa University and Dean of the College of Business and Economics. His research interests are economic development and the environment. His work so far has focused on forestry, energy, climate change, and poverty and the environment. Methodologically, he has a focus on non-market valuation techniques and (agricultural) household models. Particular areas of focus on Ethiopia include the contingent valuation of community forestry, agricultural household models applied in the context of energy, choice modelling related to health and water, rural households' tree-growing behaviour, impacts of biofuel expansion and climate change on the economy, and poverty and the environment.

Tensay H. Meles is a postdoctoral researcher at the University College Dublin School of Economics and University College Dublin Energy Institute. His research interests are energy and behavioural economics, applied econometrics, environmental valuation, and randomised field experiments. He applies a broad spectrum of advanced econometrics methods on research topics related to energy access and reliability, energy consumption behaviour, the adoption of renewable energy technologies, economic development and the environment. Currently, he is working on modelling the adoption of renewable energy technologies, such as heat pumps, solar photovoltaics, and electric vehicles.

Samuel Sebsibie is a researcher at the Environment and Climate Research Center, Policy Studies Institute, Ethiopia. He is currently working as a researcher in a research project entitled 'Impacts and Drivers of Policies for Electricity Access: Micro- and Macroeconomic evidence from Ethiopia'. His main responsibilities are project administration, work on the data management and analysis, and analysis of the data (together with other team members). He has also interest in applying econometrics tools in agricultural fields such as technology adoption.

Thomas Klug is an experienced Research Associate and Program Coordinator with a demonstrated history of working in environmental science and international development. He is a skilled in event planning, design, and data analysis, and has strong research experience and a passion for conservation, energy access, environmental economics, and ethics.

Subhrendu K. Pattanayak is the Oak Professor of Environmental and Energy Policy at Duke University. He studies the causes and consequences of human behaviours related to the natural environment to help design and evaluate policy interventions in low-income tropical countries. His research is in three domains at the intersection of environment, development, health and energy: forest ecosystem services; environmental health (diarrhoea, malaria, respiratory infections); and household energy transitions. He has focused on design of institutions and policies that are motivated by enormous inequities and a range of efficiency concerns (externalities, public goods, and imperfect information and competition).

Michael A. Toman is currently a Senior Fellow at Resources for the Future. He served as a lead economist and research team manager in the World Bank Development Research Group. He also held senior analytical and management positions at RAND Corporation and the Inter-American Development Bank. He served as a Senior Staff Economist at the White House Council of Economic Advisers from 1994 to 1996. His current research interests include climate change adaptation, international climate policy, energy and economic growth, and sustainable development.

The views expressed in this Working Paper do not necessarily reflect the UK government's official policies.